# The Whiplash Injury

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RECENT MEDICAL LITERATURE contains many articles describing the so-called "whiplash injury" received in automobile collisions. There has been very little written regarding the physical forces of static inertia and the inertia of motion by which these injuries are brought about. In the literature it has been widely reported that the injured person, describing what happened to him, often says that the car in which he was riding was struck from the rear, that he was projected forward into the windshield or the steering wheel and then felt a jerk backward. In a study of the subject the author's observations were that this sequence of events did not occur in the circumstances given.

In a study of kinematics of impact,* graphs were made showing the motions of cars involved in a front and rear collision. The rearward car in these experiments was driven by a human and in the car that was struck there was a dummy with the head fixed to the trunk by means of a coil spring having equal resistance in all planes of motion. Motion pictures were taken of collisions. The time between consecutive pictures was 1/64th of a second. At the site of collision, markers were spaced at 2-foot intervals parallel to the motion of the cars. The markers were reversed and the collisions repeated to obtain accuracy. By measuring the distance from a marker to a marked part of the car, the distance of movement of the cars was determined. Correction was made for the paralax of the position of the camera and the distance between the car and the marker. The motion of the car was plotted against time on a graph. The velocity of the car was determined by dividing the distance ordinate of the tangent at any given point of the curve by the time abscissa. The velocity, likewise, was then plotted against time. The acceleration of the car was then determined by dividing the velocity of the ordinate of the tangent to the curve by its time abscissa.

This is technically known as finding the "slope of the curve." If the slope is to the right, the value is positive and if to the left the value is negative.

For a given mass, the force acting upon it which produces motion, is proportional to the acceleration. Therefore if the acceleration and the mass involved is known, it is a simple matter to calculate the force producing the acceleration by the formula† as follows:

$$F = \frac{W}{G} \times A.$$

The purpose of the study was to answer this question:

When a car is stopped temporarily at an intersection and is bumped from the rear by another car headed in the same direction, what is the effect physically on the drivers of the two cars?

Without definite information as to the weight of each car and driver, the slope and the condition of the road, the velocity of the moving car at the time of the impact, the resilience of the bumpers, the posture of the drivers, together with other factors, this question can be answered only in a general way. Let it be assumed that the collision occurs on a level, paved highway, that the cars are of equal weight and that the car that is struck from the rear is stationary at an intersection, the driver being relaxed and not anticipating a collision. The car approaching from the rear fails to stop in time and collides with the stationary car. The driver of the moving car usually has applied his brakes before the impact, causing the front of his car to nose downward, the top of his bumper therefore hitting the lower portion of the recipient's bumper or even passing beneath it. Or, because of the variability of the height of bumpers, the bumpers might be on the same plane at the moment of impact. The bumpers of both cars will absorb some of the force of the impact, the amount depending upon their resilience. The maximum force of impact between the two cars does not occur until the bumpers or other parts of the cars are deformed to the greatest extent from the amount of force applied. Therefore, the greater the resilience, the longer the time of deceleration of the moving car and of acceleration of the stationary car, and the less the effect of the impact on the persons in the cars. During the time of impact and the partial absorption of the blow by yielding bumpers, the rearward car is decelerating at a rapid rate and the forward car is accelerating at a rapid rate. The driver of the forward car does not immediately experience this rapid acceleration, as there is a very brief interval before the impulse

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*The City of Vallejo Police Department cooperated in the present study. Vehicles used were supplied gratis by the Marine Chevrolet Company of Vallejo. The physical calculations were made by L. Bryan, A.B.D., and the photographic work was done by Carl Manner, A.B.D., both of the faculty of Vallejo Junior College.

†F = Force in pounds; W = Weight in pounds; G = Acceleration due to gravity (32 ft./sec.$^2$); A = Acceleration in ft./sec.$^2$

passes through the body of the car and is transferred to him. As the car moves forward, his body tends to remain stationary in space, since he is not in motion at the time of the impact. The effect of this is that he is thrust backward against the seat of the car, and his body, not being supported by the seat from the shoulders upward, acts and conforms as an inverted pendulum pivoting about the sacral region. The maximum degree of momentum is received by the head pivoting backward on the neck, causing it to continue its motion even after the initial or original impulse has terminated (Chart A). During this backward swing of the neck with respect to the rest of the body, there occurs a tendency toward an elongation of the neck and subsequently a protective reflex contraction of the musculature of the neck, depending upon the involuntary reflex time of the individual. This contraction of the musculature of the neck is considered a protective response comparable to that occurring when a hand is inadvertently placed on a hot stove. At approximately midway in the time duration of the impact the two cars arrive at the same velocity. Then, unless they are locked together, the cars separate owing to a rebound impulse and the effect of braking on the rearward car. At the instant of separation the forward car begins to decelerate. This deceleration rate is small compared to the acceleration that occurred upon impact. At the time deceleration begins, the body of the passenger in the forward car is still in the thrust backward position in the seat. Again there is a slight delay between the motion of the car and that of the driver. His head may not even have reached its maximum backward motion at the time the car begins to decelerate. However, in a small fraction of a second, the passenger experiences the same deceleration as the car. This causes his body to swing forward, which is further aided by his normal reflex action; and the forces by this time are much less than those obtaining at the instant of impact. The speed of the forward motion of his body is considered due to the resilience of the seat and to the acquired momentum of the body (depending upon, of course, the force of the impact and the velocity acquired during the impact and the rate of deceleration of the rest of the car); and, as previously noted, it may also be greatly increased by the recipient's reflex protective action.

The effect of collision on the driver of the rearward car is calculated as follows:

Realizing the impending impact, he suddenly applies his brakes, his muscles are tensed and he is afforded protective bracing by the steering wheel and his relation to the seat. (Such protective factors would be less if the driver were not aware of impending collision.) During the impact when the car is rapidly decelerating, his body tends to continue its forward motion, the upper portion tending to move forward faster than the lower part because of friction and bracing through the lower extremities. The amount of forward motion of the driver is determined by the amount of bracing and muscular response. If he is projected forward enough for his chest to strike the steering wheel, the pivot then would be entirely on the neck. A rider in the front seat of the car, if he is not anticipating the collision, would be projected forward against the nearest impediment—usually the dashboard—in the interior of the car, which he would strike with a velocity about equal to that of the car in which he was riding at the instant of impact, minus the mutual velocity at which the two cars had arrived before separating. Roughly, the velocity of the rider hitting against the dashboard would be about half that of the car in which he was riding when collision occurred.

The weights of the involved cars are also important factors and bear relationship to the degree of force impact. In general, if the car in motion is heavier than the stationary car, the stationary car will be forced to a greater velocity in relation to the velocity of the moving car, and consequently will have a greater acceleration than if it were heavier than the moving car. If the stationary car is the heavier, the converse is true.

The accompanying chart was made from data obtained from photographic timing correlated by mathematical equations. As revealed by the position of the head of the dummy in the car that was stationary and was struck from the rear, the first motion of the head on impact is backward and subsequently forward.

In these studies no attempt was made to correlate the degree of injury in relation to the velocity of impact. Experience in treating such injuries indicates they frequently occur in collisions in which the impact of collision was relatively light.

In an analysis of 40 consecutive cases of whiplash injuries, all of which were subjects of civil litigation, it is significant that in no instance in the series was it ascertained that an occupant of the car approaching from the rear received a cervical or whiplash injury. This can be explained by the precollision protective reflexes set in motion in the driver passengers. For the sake of clarity, the symptoms and objective findings in the 40 cases are discussed briefly under the following headings:

*A. Number of patients who had immediate traction to neck, 2 (5 per cent).*

Apparently immediate cervical traction, applied before muscular spasm occurs or soon after the onset of muscular spasm, appreciably decreased the

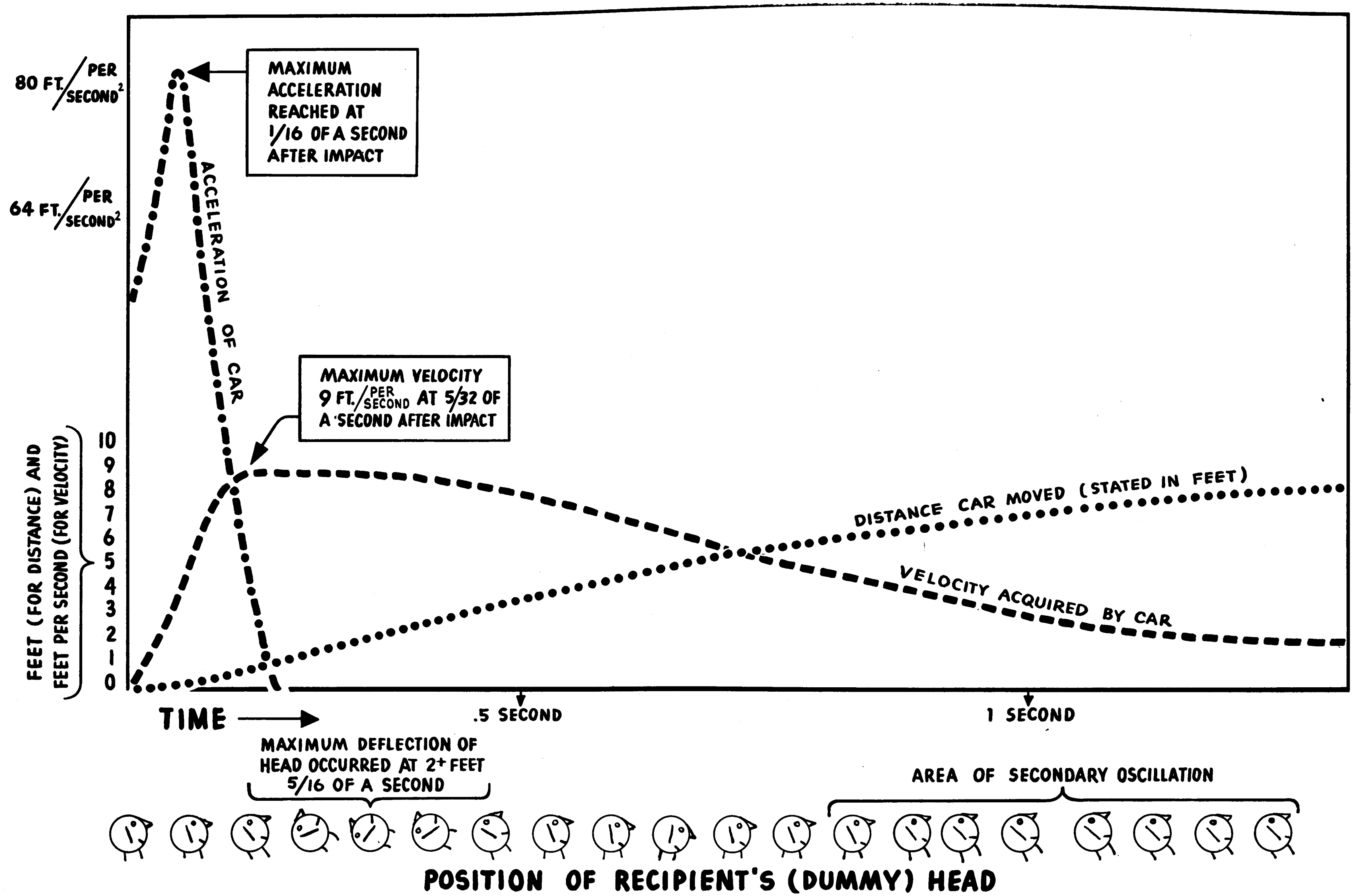


Chart A.—Data on the effect of impact on a stationary automobile struck from the rear by another automobile. The speed of the rearward car was 10 miles per hour (14.6 feet per second) at the moment of impact. In the stationary car the coil spring which supported the dummy's head had equal resistance to motion in the vertical planes.

recovery period and consistent relief from discomfort correlated the relaxation afforded by traction. In these cases of potential pain from whiplash injuries, the often associated symptomatology of headache, anxiety, personality changes, et cetera, did not develop, possibly because traction lessened the muscular contraction of the neck, increased the intervertebral spaces and to some extent also increased the aperture of the nerve root foramen, thus giving symptomatic relief and forfending the development of the cycle of secondary symptoms.

B. *Number of cases in which application of traction or cervical collar was delayed, 20 (50 per cent).*

There was apparently a relationship between emotional build-up and the lapse of time before cervical traction or a cervical collar was applied for relief of pain. It is believed that in such cases a good deal of emotional and anxiety apprehension could be avoided if the patient were thoroughly informed as to the problems of treatment and the pain, headaches and other symptoms to be anticipated, and as to the time needed for maximum recovery.

C. *Number of whiplash cases in which there was associated cervical fracture, 1 (2.5 per cent).*

In this instance the inferior articulating process of the fifth cervical vertebra was fractured. There was an associated fracture of the spinous processes of the sixth vertebra.

D. *Number of patients who had immediate pain or radiating pain into either upper extremity or involvement of brachial plexus, 1 (2.5 per cent).*
*Number who had delayed radiating pain into either upper extremity or involvement of brachial plexus, 17 (42.5 per cent).*

That immediate pain or radiating pain involving the upper extremities occurred in only one case in forty is indicative that the structure of the cervical neck is capable of withstanding sudden flexion and extension motions without primary nerve injury. In those cases in which there was delayed radiating pain into either upper extremity, the symptom was assumed to be produced by nerve root edema with impingement at the foramen orifice causing pressure on the nerve. This usually occurs in from 6 to 24 hours after the accident. Nerve root edema is theoretically decreased by immobilization, rest and traction.

In none of the 17 cases was there permanent paralysis involving the medial, radial or ulnar nerves. Six of the 17 patients had motor weakness with sensitory changes in the extremities, two had motor weakness without sensitory changes and four had sensitory changes without motor weakness. Five of the 17 patients had decreased hand compression strength (by Geckler dynamometer comparison with the uninvolved hand, with allowance made for difference between major and minor hand).

E. *Number of proved disc injuries diagnosed by the author or by other physicians who examined some of the patients, none.*

F. *Number of patients who had associated arthritic changes of the cervical vertebra, 13 (32.5 per cent).*

In these 13 cases an attempt was made to determine whether the whiplash injury exacerbated preexisting arthritic changes, using the following criteria:

1. Comparative x-ray films to determine changes beyond the usual ones to be anticipated over the time interval.

2. Repeated evaluation of the integrity of the patient in relation to the subjective complaints referable to arthritis.

3. Estimation of the force of the impact that caused the injury, the position of the patient at impact if determinable, the position of the patient immediately after impact and the position finally assumed—whether thrown free of the car or against the structure of the interior of the car.

The findings were inconclusive. In many cases there was no radiologically perceptible change, no impairment of the range of normal motion of the cervical vertebra and no increase or persistency of radicular pain.

G. *Number of patients with associated concussion or commotio cerebri, 19 (47.5 per cent).*
   *(a) Number with moderate concussion, dazed one hour or less, 17 (42.5 per cent).*
   *(b) Number unconscious for one hour or more, 2 (5 per cent).*

In the 17 cases of moderate concussion, vertigo and headache were the most prominent and persistent symptoms. Two of the 17 patients had systematized vertigo, which was considered to indicate that the system for control of balance and position was involved. The other 15 had nonsystematized vertigo which was considered a component of the postconcussional syndrome after examination to determine that it could not be validly attributed to organic disease elsewhere in the body.

H. *Number of patients who had electroencephalogic changes indicative of trauma, 4 (10 per cent).*

In this connection, question arises as to how long patients with positive electroencephalogic change must be observed, and by what methods examined, to be sure that sequelae will not develop. The answer to this question must be given by those who are specialists in this field.

*I. Number of cases in which caloric and hearing tests were used as a positive adjunct to diagnosis, 2 (5 per cent).*

Caloric tests were found extremely valuable in diagnosis. They should be performed in all cases of whiplash injury in which the patient persistently complains of vertigo. In both cases in which these tests were done in the present series there was associated concussion.

*J. Number of patients with objective palpable muscular spasm in neck independent of subjective complaints, 18 (45 per cent).*

A routine procedure was followed in palpating muscular spasm referable to the neck. Light and firm palpation was repeated while the attention of the patient was distracted. There was a direct positive relation of the degree of spasm to the ability of the person examined to particularize this subjective complaint. Muscular spasm must be ascertained with the patient both upright and recumbent.

*K. Number of patients subconsciously or consciously exaggerating the subjective symptoms referable to neck, 5 (12.5 per cent).*

It is the author's opinion that five patients definitely exaggerated the subjective symptoms. The minor exaggerations referable to subjective symptoms in many cases were disregarded and are not included here.

*L. Number of patients complaining of headache, 22 (55 per cent).*

Before attributing headache to a whiplash injury, full consideration must be given to other possible causes—neuralgic, allergic and tensive, for example. Muscular spasm, if present, is almost invariably accompanied by headache. Myofascitis of the cervical structures, periarthritis and arthritis are all capable of producing various degrees of headache. Determining whether or not it is related to the whiplash injury may be difficult.

*M. Number of patients who had emotional disturbance, 9 (22.5 per cent).*

The emotional disturbances which accompany whiplash injuries have been described in detail by numerous neurologists and neuropsychiatrists. From their experience and writings it is well authenticated that the emotional disturbance is a component of the postconcussional syndrome.

*N. Number who had cervical dislocations, 1 (2.5 per cent).*

It is quite conceivable and theoretically sound that patients receiving moderate or severe whiplash injury could have partial dislocation of the cervical vertebra, and then immediate and spontaneous reduction. So far as could be determined in the present series there was no way by which to determine the degree of force in a specific case and the relationship of the force to the production of dislocation. In considering the possibility of spontaneous reduction of cervical dislocation occurring before radiological studies can be made, it would be expected in such cases that the symptoms might be persistent and objective findings more prolonged than in cases of minimal or moderate injury at the site of ligamentous and fascial attachment.

It is quite apparent from the physical factors involved, both as to the force of impact and the structure of the individual, that there is ground for a wide diversity of opinion among medical examiners in evaluating the injury from a legal standpoint. The admitted medical unknowns create a fertile field for litigation as applicable to whiplash injuries. It follows that the medical examiner in such cases should convey in reports and, when necessary, in testimony, direct and unbiased opinions based upon proved substantiated medical knowns from a structural and physiological standpoint. Only by so doing can a reasonable degree of certainty be obtained.

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